

1 TOGGLE INTERLOCKED THRUST REVERSER

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3 [0001] This application claims the benefit of U.S. Provisional Applications 60/456,710; filed  
4 3/22/03; and 60/478,163; filed 6/13/03.

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BACKGROUND OF THE INVENTION

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8 [0002] The present invention relates generally to aircraft engines, and, more specifically, to  
9 thrust reversers therein.

10 [0003] A typical turbofan aircraft engine includes a fan powered by a core engine for  
11 producing propulsion thrust for powering the aircraft in flight. The core engine typically has  
12 in serial flow communication a multistage axial compressor, annular combustor, and high  
13 pressure turbine joined to the compressor by one shaft. A second shaft joins the fan to a low  
14 pressure turbine disposed downstream from the high pressure turbine.

15 [0004] The engine also includes a fan nacelle surrounding the cowling or nacelle of the core  
16 engine which defines an annular bypass duct therebetween. The nacelle may be short and  
17 terminates in a fan outlet nozzle surrounding the core engine upstream from an independent  
18 core exhaust nozzle at the downstream end thereof. Or, the fan nacelle may be long and  
19 extends downstream past the core nozzle for collectively discharging both the fan bypass air  
20 and the core exhaust in a common exhaust nozzle disposed downstream therefrom.

21 [0005] The turbofan engine typically also includes a fan thrust reverser for providing  
22 aerodynamic braking during aircraft landing on a runway. Various types of fan thrust  
23 reversers are known in the art, one of which includes pivoting doors that block the aft travel of  
24 the fan air in the bypass duct and redirect it in the forward direction for reversing the direction  
25 of fan air thrust.

26 [0006] The known fan reversers have various advantages and various disadvantages relating  
27 to complexity, size, weight, and cost. And, the pivoting door fan reverser requires redundant  
28 locking or latching devices for preventing inadvertent in-flight deployment thereof.

29 [0007] In a large turbofan engine, there may be four pivoting doors spaced around the  
30 nacelle, with each of those four doors requiring three independent latches for satisfying

1 government certification requirements. Accordingly, twelve independent latches would be  
2 required for the entire fan reverser, and correspondingly increase the complexity and cost of  
3 the reverser system and its control.

4 **[0008]** U.S. Patent Application No. 10/679,882; filed 10/06/2003, and assigned to the  
5 present assignee, discloses an improved bifold door thrust reverser having many advantages  
6 over typical fan thrust reversers. The bifold door reverser includes outer and inner doors  
7 which are deployed in opposition for blocking and turning the fan bypass flow during thrust  
8 reverse operation. A gang of the outer doors may be deployed in unison with a common inner  
9 door, all deployed using a common actuator.

10 **[0009]** The outer and inner doors maintain continuity of the outer and inner skins of the  
11 nacelle when stowed, and the actuation mechanism is fully contained in the nacelle between  
12 the two skins. The bifold door reverser is relatively compact and requires relatively small  
13 stroke of the actuators used therein.

14 **[0010]** And, the compact and nested configuration of the outer and inner doors in the bifold  
15 door reverser permit therein the introduction of a new locking or latching system as further  
16 described hereinbelow.

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#### 18 BRIEF SUMMARY OF THE INVENTION

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20 **[0011]** A fan thrust reverser includes a nacelle having radially outer and inner skins. An  
21 outer door is disposed in the outer skin, and mounted to the nacelle at a hinge joint. A toggle  
22 link is pivotally joined between the outer door and the nacelle for latching stowed the outer  
23 door in the nacelle. An actuator is provided for rotating the outer door about the hinge joint  
24 for deploying the door outwardly from the nacelle and toggling off the toggle link, and  
25 stowing inwardly the outer door upon reverse rotation thereof and toggling on the toggle link  
26 to latch the door stowed in the nacelle.

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#### 28 BRIEF DESCRIPTION OF THE DRAWINGS

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30 **[0012]** The invention, in accordance with preferred and exemplary embodiments, together

1 with further objects and advantages thereof, is more particularly described in the following  
2 detailed description taken in conjunction with the accompanying drawings in which:

3 [0013] Figure 1 is a partly sectional axial view of an exemplary turbofan aircraft gas turbine  
4 engine mounted to an aircraft wing, and including a fan thrust reverser integrated in the fan  
5 nacelle thereof.

6 [0014] Figure 2 is an isometric view of a symmetrical half of the fan nacelle shown in  
7 Figure 1 illustrating deployment of the fan thrust reverser therein.

8 [0015] Figure 3 is a radial sectional view of the nacelle illustrated in Figure 2 and taken  
9 generally along line 3-3.

10 [0016] Figure 4 is an enlarged isometric view of a representative set of the reverser doors  
11 illustrated in Figure 2 in an exemplary embodiment.

12 [0017] Figure 5 is an axial sectional view of the fan reverser illustrated in Figures 1-4 in a  
13 stowed position.

14 [0018] Figure 6 is an axial sectional view of the fan reverser illustrated in Figure 5 shown in  
15 a deployed position.

16 [0019] Figure 7 is an enlarged axial sectional view through an aft portion of the fan reverser  
17 illustrated in Figure 5 showing a pair of toggle links in accordance with an exemplary  
18 embodiment.

19 [0020] Figure 8 is an enlarged view of the mounted forward toggle link illustrated in Figure  
20 7.

21 [0021] Figure 9 is an isolated view of the toggle link in accordance with an exemplary  
22 embodiment.

23 [0022] Figure 10 is a radially outwardly facing planiform view of a portion of the fan  
24 reverser illustrated in Figure 5 and taken generally along line 10-10.

25 [0023] Figure 11 is an isolated isometric view of the forward outer door of the fan reverser  
26 illustrated in Figure 5.

27 [0024] Figure 12 is an inboard isometric view of the aft outer door of the fan reverser  
28 illustrated in Figure 5.

29 [0025] Figure 13 is an outboard isometric view of the aft outer door of the fan reverser  
30 illustrated in Figure 5.

1 [0026] Figure 14 is an isolated isometric view of the inner blocker door of the fan reverser  
2 illustrated in Figure 5.

3 [0027] Figure 15 is an enlarged axial sectional view of an additional locking mechanism for  
4 the forward outer door stowed closed in the fan reverser illustrated in Figure 5.

5 [0028] Figure 16 is an enlarged axial sectional view, like Figure 15, of the locking  
6 mechanism as the forward outer door is deployed open.

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8 DETAILED DESCRIPTION OF THE INVENTION

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10 [0029] Illustrated in Figure 1 is a turbofan aircraft gas turbine engine 10 suitably mounted to  
11 the wing 12 of an aircraft by a supporting pylon 14. Alternatively, the engine could be  
12 mounted to the fuselage of the aircraft if desired.

13 [0030] The engine includes an annular fan nacelle 16 surrounding a fan 18 which is powered  
14 by a core engine surrounded by a core nacelle or cowl 20. The core engine includes in serial  
15 flow communication a multistage axial compressor 22, an annular combustor 24, a high  
16 pressure turbine 26, and a low pressure turbine 28 which are axisymmetrical about a  
17 longitudinal or axial centerline axis 30.

18 [0031] During operation, ambient air 32 enters the fan nacelle and flows past the fan blades  
19 into the compressor 22 for pressurization. The compressed air is mixed with fuel in the  
20 combustor 24 for generating hot combustion gases 34 which are discharged through the high  
21 and low pressure turbine 26,28 in turn. The turbines extract energy from the combustion  
22 gases and power the compressor 22 and fan 18, respectively.

23 [0032] A majority of the air is pressurized by the driven fan 18 for producing a substantial  
24 portion of the propulsion thrust powering the aircraft in flight. The combustion gases 34 are  
25 exhausted from the aft outlet of the core engine for providing additional thrust.

26 [0033] However, during landing operation of the aircraft, thrust reversal is desired for  
27 aerodynamically slowing or braking the speed of the aircraft as it decelerates along a runway.  
28 Accordingly, the turbofan engine 10 includes a fan thrust reverser 36 wholly contained in or  
29 integrated into the fan nacelle 16 for selectively reversing fan thrust during aircraft landing.

30 [0034] The fan thrust reverser, or simply fan reverser 36 is integrated directly into the fan

1 nacelle 16. The fan nacelle includes radially outer and inner cowlings or skins 38,40 which  
2 extend axially from a leading edge of the nacelle defining an annular inlet 42 to an opposite  
3 trailing edge defining an annular outlet 44. As additionally shown in Figures 2 and 3, the fan  
4 nacelle 16 may have any conventional configuration, and is typically formed in two generally  
5 C-shaped halves which are pivotally joined to the supporting pylon 14 for being opened  
6 during maintenance operations.

7 **[0035]** The exemplary fan nacelle illustrated in Figures 1-4 is a short nacelle terminating  
8 near the middle of the core engine for discharging the pressurized fan airflow separately from  
9 and surrounding the exhaust flow 34 discharged from the aft outlet of the core engine. In  
10 alternate embodiments, the fan nacelle could be long and extend downstream of the core  
11 engine for providing a single, common outlet for both the fan air and the core exhaust.

12 **[0036]** In the exemplary embodiment illustrated in Figure 1, the core engine is mounted  
13 concentrically inside the fan nacelle 16 by a row of supporting struts in a conventional  
14 manner. The core cowl 20 is spaced radially inwardly from the inner skin 40 of the fan  
15 nacelle to define an annular bypass duct 46 therebetween which bypasses a major portion of  
16 the fan air around the core engine during operation. The fan bypass duct terminates in an  
17 annular fan nozzle 48 at the nacelle trailing edge or outlet 44.

18 **[0037]** A particular advantage of the fan reverser 36 is that the fan nozzle 48 itself may  
19 remain fixed at the aft end of the fan nacelle surrounding the core engine. And, the fan  
20 reverser 36 may be fully integrated in the fan nacelle immediately forward or upstream from  
21 the fixed fan nozzle.

22 **[0038]** More specifically, the fan reverser is illustrated in more detail in Figures 5 and 6  
23 wherein the outer and inner skins 38,40 are spaced radially apart to define an arcuate  
24 compartment or annulus 50 spaced axially forwardly from the nacelle trailing edge 44. The  
25 nacelle compartment 50 includes a flow tunnel or aperture 52 extending radially between the  
26 inner and outer skins through which the pressurized fan bypass air 32 may be discharged  
27 during thrust reverse operation.

28 **[0039]** At least one, and preferably a gang or set of radially outer louver doors 54,56 are  
29 suitably pivotally joined to the fan nacelle in the compartment 50 to close the exit end of the  
30 tunnel along the outer skin 38. Two or more of the louver doors may be axially nested

1 together as further described hereinbelow.

2 [0040] A corresponding radially inner reverser or blocker door 58 is suitably pivotally  
3 joined to the fan nacelle 16 inside the compartment 50 in radial opposition with the gang of  
4 louver doors to close the inlet end of the tunnel along the inner skin 40. In the stowed closed  
5 position illustrated in Figure 5, the inner door is folded closed generally parallel with the  
6 corresponding gang of outer doors, converging slightly to conform with the converging profile  
7 or cross section of the nacelle.

8 [0041] Since the fan bypass duct 46 illustrated in Figures 1-3 is substantially annular, the fan  
9 reverser includes corresponding groups of the louver doors 54,56 and cooperating blocker  
10 door 58 spaced circumferentially apart around the perimeter of the fan nacelle 16. For  
11 example, in each half C-duct portion of the fan nacelle, three groups of the blocker and louver  
12 doors are uniformly spaced apart from each other.

13 [0042] The three blocker doors 58 in each nacelle half preferably have trapezoidal  
14 configurations for circumferentially adjoining each other inside the inner skin 40 when  
15 deployed as illustrated in Figure 3 for blocking the fan flow from exiting through the fan  
16 nozzle. Instead, the fan flow is diverted through the open louver doors as illustrated in Figure  
17 2 and directed axially forwardly for providing thrust reverse operation in landing of the  
18 aircraft.

19 [0043] An elongate drive link 60 pivotally joins together the outer and inner doors for  
20 coordinating the simultaneous deployment thereof. Means in the form of a linear drive  
21 actuator 62 are suitably mounted in the nacelle compartment and joined to the doors for  
22 selective rotation thereof from the stowed position illustrated in Figure 5 at which the doors  
23 are pivoted closed substantially flush in the outer and inner skins 38,40 respectively.

24 [0044] For example, in Figures 5 and 6, the drive actuator 62 is pivotally joined to the fan  
25 nacelle in a suitable cradle inside the reverser compartment 50, and the output rod thereof is  
26 directly pivotally joined to the middle of the forward louver door 54. In this way, the output  
27 rod of the actuator 62 is unconstrained to move with the forward louver door 54 as it rotates  
28 between the deployed and stowed positions.

29 [0045] The actuator 62 may be operated in reverse for rotating the doors to the deployed  
30 position illustrated in Figure 6 at which the outer doors 54,56 are pivoted open and extend

1 radially outwardly in part from the outer skin 38, with the inner door 58 being pivoted open  
2 and extending radially inwardly in most part from the inner skin 40. The outer and inner  
3 doors are interconnected by the drive link 60 in an accordion or bifold manner in which the  
4 doors collapse or fold together in the stowed position illustrated in Figure 5, and swing open  
5 with opposite inclinations in the deployed position illustrated in Figure 6.

6 **[0046]** The bifold configuration of the outer louver doors and inner blocker door permits all  
7 the components of the fan reverser to be integrated and hidden within the axial extent of the  
8 radial compartment 50 between the outer and inner skins. The doors 54-58, the drive link 60,  
9 and the drive actuator 62 are fully contained within the compartment in the stowed position  
10 illustrated in Figure 5 without any flow obstruction by these reverser components inside the  
11 inner skin 40 of the nacelle.

12 **[0047]** In this way, the inner skin 40 including the stowed blocker door 58, maintains a  
13 substantially smooth and flush inner boundary or flow contour of the fan nacelle surrounding  
14 the bypass duct 46 for maintaining aerodynamic efficiency of the fan air discharged  
15 therethrough without obstruction. And, the outer skin 38 including the stowed louver doors  
16 54,56 remains substantially smooth and flush for minimizing aerodynamic drag as the engine  
17 propels the aircraft at altitude.

18 **[0048]** In the preferred embodiment illustrated in Figures 5 and 6, a pair of the outer louver  
19 doors 54,56 are arranged in axial series in the common flow tunnel 52 in axial and  
20 circumferential alignment atop the common blocker door 58 disposed therebelow. An  
21 elongate unison link 64 pivotally joins together the gang of louver doors 54 so that they may  
22 open and close simultaneously in the manner of commonly known louver windows.

23 **[0049]** The common drive link 60 pivotally joins together the gang of louver doors and the  
24 complementary blocker door 58. The drive actuator 62 may then be used for deploying  
25 outwardly in unison the louver doors as the cooperating blocker door is simultaneously  
26 deployed inwardly. In this way, the one set of blocker and louver doors may be deployed  
27 simultaneously as the doors unfold from each other, with the louver doors being inclined  
28 radially outwardly and facing forwardly, and the blocker door being inclined radially inwardly  
29 and forwardly in the deployed position illustrated in Figure 6.

30 **[0050]** The louver doors 54,56 illustrated in Figures 4-7 are configured for multiple purposes

1 including smoothly closing the flow tunnel in the outer skin 38 when the louvers are stowed  
2 closed. And, when deployed open, the louver doors are inclined radially outwardly and  
3 forwardly for reversing direction of the fan bypass flow 32 for fan thrust reversal, while  
4 additionally turning the airflow through the flow tunnel.

5 **[0051]** Correspondingly, the inner blocker door 58 illustrated in Figure 6 may be deployed  
6 radially inwardly into the bypass duct 46 in unfolding or bifold opposition with the outer  
7 louver doors 54,56. The blocker door 58 is suitably sized in axial length to radially reach the  
8 core cowl 20 when deployed. The blocker door therefore bridges the entire radial extent of the  
9 bypass duct 46 for blocking and diverting the fan bypass flow 32 radially outwardly into the  
10 oppositely inclined open louver doors which redirect the bypass flow axially forwardly for  
11 thrust reverse operation.

12 **[0052]** The louver doors 54,56 and blocker door 58 may be suitably mounted to the fan  
13 nacelle in any convenient manner for effecting the improved deployment thereof as described  
14 above. For example, a pair of circumferentially spaced apart cantilevers 66 have  
15 corresponding proximal ends which are suitably fixedly mounted to the nacelle in the  
16 common compartment 50. The cantilevers are preferably thin beams circumferentially and  
17 thick radially to provide sufficient strength for supporting the louver doors therefrom while  
18 minimizing obstruction of the airflow during thrust reverse operation. As shown in Figure 4,  
19 the two cantilevers 66 define with the two deployed louver doors a grate like those typically  
20 found in fixed cascade vanes, but using the movable louver doors.

21 **[0053]** The aft louver door 56 is suitably pivotally joined to the distal ends of the two  
22 cantilevers, with the forward louver door 54 being pivotally joined at an intermediate location  
23 on the cantilevers forward of the aft distal end thereof. In this way, the thin cantilevers  
24 support the louver doors under tension against the aerodynamic pressure loads exerted on the  
25 louver doors when deployed.

26 **[0054]** In Figures 4-6, a pair of the unison links 64 are correspondingly mounted to the  
27 louver doors 54,56 axially along respective ones of the two cantilevers 66. And, two  
28 corresponding drive links 60 extend from the aft ends of the unison links to the forward ends  
29 of the blocker doors.

30 **[0055]** The output rod of the pivoted actuator 62 may then be conveniently mounted to a



1 suitable clevis at the middle of the forward louver door 54 between the two cantilevers as  
2 illustrated in Figure 4. Deployment of the forward louver door in turn deploys the aft louver  
3 door and the common blocker door interconnected by the pairs of unison links 64 and drive  
4 links 60.

5 [0056] The various pivotal connections or joints required for the louver and blocker doors,  
6 actuating links, and drive actuator may be provided in any conventional manner. For  
7 example, suitable clevis brackets may be fixedly joined to the doors as illustrated in Figures  
8 10-14 for pin mounting to the cantilevers, links, and corresponding internal frames in the  
9 nacelle.

10 [0057] In the preferred embodiment illustrated in Figures 4,6,12,13 the unison link 64 is  
11 pivotally joined to the two louver doors 54 in corresponding clevises thereon mounted in the  
12 louver doors aft of the clevises which pivotally join the louver doors to the cantilevers in the  
13 nacelle. In this way, the various components of the actuating means may be fully contained  
14 within the nacelle compartment 50 for efficiently kinematically opening and closing the doors  
15 in unison.

16 [0058] In the preferred embodiment illustrated in Figure 6, the drive link 60 is pivotally  
17 joined between the aft end of the unison link 64 and the forward end of the blocker door 58.  
18 In this way, as the unison link is deployed aft in the nacelle, the drive link opens inwardly the  
19 attached blocker door which pivots at its aft end. Correspondingly, retraction forwardly of the  
20 unison link retracts outwardly the drive link and the attached blocker door to the stowed  
21 position illustrated in Figure 5.

22 [0059] In Figure 5, extension of the actuator rod in turn pushes aft the unison link 64 for  
23 pivoting closed the louver doors on their respective pivot joints while also pivoting closed the  
24 interconnected blocker door. In Figure 6 the actuator rod is retracted forwardly which in turn  
25 pulls the unison link 64 forwardly for pivoting open the two louver doors around their  
26 respective pivot axes while driving radially inwardly the drive link for opening the blocker  
27 door.

28 [0060] Although extension of the actuator 62 illustrated in Figure 5, and the internal pressure  
29 of the fan bypass flow 32 cooperate to maintain closed the blocker and louver doors, it is also  
30 desirable to provide a further mechanism for locking closed the doors of the thrust reverser.

1 [0061] More specifically, the interconnected bifold configuration of the louver doors 54,56  
2 and the cooperating blocker door 58 permits the introduction of a relatively simple mechanism  
3 for self-locking or self-latching the cooperating doors in their stowed positions without the  
4 need for external power or control dedicated thereto. This self-locking capability is effected  
5 by introducing one or more substantially identical toggle links 68 suitably pivotally joined  
6 between one or both louver doors 54,56 and the supporting nacelle 16 as illustrated in Figures  
7 5 and 6, for example. Each toggle link is preferentially joined to the corresponding louver  
8 door for biasing or latching stowed in the closed position that louver door flush in the outer  
9 skin of the nacelle. The toggle link works in combination with the drive actuator 62 as it  
10 deploys open and stows closed the louver doors.

11 [0062] Figure 7 illustrates in enlargement the hinge mounting of the two louver doors 54,56  
12 to the supporting cantilevers 66. Each louver door includes a suitable hinge joint 70 formed  
13 with the cantilevers 66 by corresponding hinge pins extending therethrough. Each joint may  
14 include a suitable clevis fixedly mounted to the inboard surface of the louver doors in which  
15 the thin cantilever is disposed and pivotally secured thereto by a hinge pin.

16 [0063] In this way, each of the louver doors as illustrated in Figure 6 may be rotated open or  
17 rotated closed by the interconnected output rod of the drive actuator 62 when desired. The  
18 corresponding toggle link 68 may be used in conjunction with rotation of the louver doors for  
19 providing a biasing force to maintain closed the louver doors in their stowed positions.

20 [0064] The two exemplary toggle links 68 illustrated in Figure 7 may be identical in  
21 configuration, but suitably different in size and orientation for cooperating with the two louver  
22 doors 54,56. Figure 8 is a further enlarged view of the forward toggle link 68 attached to the  
23 forward louver door 54, and is representative also of the aft toggle link similarly attached to  
24 the aft louver door 56 illustrated in Figure 7.

25 [0065] As illustrated in Figure 8, the toggle link 68 includes a proximal end 72 pivotally  
26 joined to the supporting nacelle and spaced away from the hinge joint 70, and an opposite  
27 distal end 74 disposed generally therebetween.

28 [0066] In Figure 7, the proximal end of the forward toggle link may be pivotally joined to a  
29 bracket 76 fixedly joined to the bottom of the cantilever 66. Correspondingly, the proximal  
30 end of the aft toggle link may be pivotally joined to another bracket 78 fixedly mounted to an

1 adjacent frame in the nacelle.

2 **[0067]** The proximal ends of the two toggle links illustrated in Figure 7 are suitably spaced  
3 away from the corresponding hinge joints 70 to define corresponding, straight toggle lines or  
4 centerlines 80 therebetween.

5 **[0068]** For each toggle link, the opposite distal end 74 thereof is disposed between its  
6 proximal end 72 and the corresponding hinge joint 70 laterally offset or off-center from the  
7 corresponding toggle line 80 as illustrated in both Figure 7 and 8.

8 **[0069]** For the forward toggle link 68 illustrated in Figures 6 and 7, its distal end 74 is  
9 laterally offset axially aft in the outboard direction of the forward toggle line 80 in the stowed  
10 position of the forward louver door 54, and oppositely laterally offset axially forwardly in the  
11 inboard direction of the forward toggle line in the deployed position of the forward louver  
12 door. In other words, the toggle link 68 toggles between the opposite sides of the toggle line  
13 80 relative to the corresponding hinge axis 70 of the forward louver door 54.

14 **[0070]** Correspondingly, for the aft toggle link illustrated in Figures 6 and 7, the distal end  
15 74 thereof is laterally offset radially outwardly in the outboard direction of the aft toggle line  
16 80 in the stowed position of the door, and oppositely laterally offset radially inwardly of aft  
17 toggle line in the deployed position of the aft louver door. The aft toggle link 68 therefore  
18 similarly toggles between the opposite sides of the aft toggle line 80 between the stowed and  
19 deployed positions of the aft louver door 56.

20 **[0071]** The forward and aft toggle links 68 are illustrated schematically in Figures 6-8, and  
21 are preferably telescopic and vary in length as they are toggled during operation. The toggle  
22 links are suitably configured for requiring increasing compression force as their lengths  
23 decrease between their opposite proximal and distal ends.

24 **[0072]** Figure 9 illustrates an exemplary embodiment of the two toggle links 68. Each link  
25 may include an elongate rod extending from the proximal end 72 which is correspondingly  
26 received inside an elongate cylinder 84 fixedly joined to the distal end 74. A compression  
27 spring 86 surrounds the rod 82 inside the cylinder 84, and effects a reaction force F in  
28 response to the compression of the toggle link that decreases its length as the spring is  
29 compressed inside the cylinder. A suitable tubular shield or casing 88 surrounds the spring  
30 from the proximal end 72 and telescopes inside the cylinder 84 during compression and

1 expansion of the toggle link during use.

2 [0073] In alternate embodiments, the toggle link 68 may be pneumatic or hydraulic, instead  
3 of using the compression spring therein, for introducing the reaction force to compression  
4 thereof in any conventional manner.

5 [0074] As illustrated in Figures 5 and 8, the forward toggle link 68 has a first length A  
6 between its opposite proximal and distal ends in the stowed position of the forward louver  
7 door. As the forward louver door 54 is rotated from its stowed position in Figure 8 to its  
8 deployed position in Figure 6, the distal end 74 of the link is forced by the rotating louver door  
9 towards the opposite proximal end 72 of the link, which decreases the link length from the  
10 first length A to a minimum length B along the toggle line 80, and then the link increases in  
11 length to a larger second length C when the forward louver door is fully deployed. The length  
12 of the toggle link when aligned along the toggle line 80 is the minimum length of the toggle  
13 link since the louver door rotates about the hinge joint 70 which carries the link distal end 74  
14 along a small arc therearound.

15 [0075] This configuration and orientation of the toggle links 68 illustrated in Figure 8 may  
16 be used to provide a substantial reaction force F on the outboard side of the toggle link 80  
17 which in turn creates a counterclockwise closing moment or couple M1 for maintaining closed  
18 the forward louver door in its stowed position. The toggle link 68 is thusly toggled-on in its  
19 outboard position illustrated in Figure 8 for developing the counterclockwise moment M1.

20 [0076] In contrast, when the forward toggle link 68 is toggled inboard of its toggle line 80 as  
21 illustrated in Figure 6 to its toggle-off position, a corresponding reaction force is developed in  
22 the toggle link which in turn creates a clockwise opening moment or couple M2 which assists  
23 the drive actuator in maintaining open in the deployed position the forward louver door.

24 [0077] In either on or off position of the forward toggle link 68, the drive actuator 62 must  
25 be energized for deploying open the forward louver door or stowing closed the forward louver  
26 door while also compressing the forward toggle link 68 to its minimum length B as it toggles  
27 between the opposite sides of the toggle line 80. In either position on opposite sides of the  
28 toggle line, the compressed toggle link 68 is offset or over-center and develops the reaction  
29 force F and the corresponding clockwise or counterclockwise moments exerted on the forward  
30 louver door.

1 [0078] In the preferred embodiment illustrated in Figure 8, the kinematic geometry of the  
2 rotating louver door and rotating forward toggle link are selected so that the second or toggle-  
3 off length C of the forward toggle link 68 is smaller than the first or toggle-on length A of the  
4 forward toggle link so that the clockwise deploying moment M2 is greater than the  
5 counterclockwise stowing moment M1. The force requirements for the corresponding drive  
6 actuator 62 may therefore complement the forces and moments developed by the forward  
7 toggle link 68.

8 [0079] Figure 10 illustrates the inside view of the aft portion of the forward louver door 54,  
9 with Figure 11 illustrating the forward louver door 54 in isolation. Figure 11 illustrates clearly  
10 a pair of the forward toggle links 68 pivotally joined to the inboard side of the forward louver  
11 door 54 at corresponding clevises 90 provided therefor.

12 [0080] As illustrated in Figures 7 and 12, the aft louver door 56 includes a pair of the hinge  
13 joints 70 defined by suitable clevises joined to the inboard side thereof. Correspondingly,  
14 Figures 7 and 13 illustrate a pair of the aft toggle links 68 pivotally joined to the outboard side  
15 of the aft louver door 56 in suitable clevises 90 substantially identical to those used for the  
16 forward toggle links.

17 [0081] The aft toggle link 68 illustrated in Figures 5 and 6 functions in the same manner as  
18 the forward toggle link 68, but is sized and oriented differently for cooperating with the aft  
19 louver door 56. For example, the distal end of the aft toggle link 68 illustrated in Figure 5 is  
20 disposed radially outboard of the aft toggle line 80 in the stowed position of the aft louver  
21 door, and radially inboard of the aft toggle line in the deployed position of the aft louver door  
22 as illustrated in Figure 6.

23 [0082] Correspondingly, the aft toggle link 68 illustrated in Figure 5 has a first length D in  
24 the stowed position which decreases to its minimum length along the aft toggle link 80 as the  
25 aft louver door is deployed, and then increases to the second length E when the aft louver door  
26 is fully deployed.

27 [0083] The aft toggle link 68, like the forward toggle link described above, effects a reaction  
28 force as the toggle link is compressed for generating a counterclockwise moment in Figure 5  
29 for maintaining closed the aft louver door, and a clockwise moment in Figure 6 for  
30 maintaining open the aft louver door when deployed. The deployed length E of the aft toggle

1 link 68 may be smaller than the stowed length D thereof, for effecting greater deploying  
2 moment than stowing moment.

3 [0084] Accordingly, the forward toggle link 68 may be used with the forward louver door  
4 54. The aft toggle link 68 may be used with the aft louver door 56. And, the forward and aft  
5 toggle links may be used solely on either of the two louver doors, or on both the louver doors  
6 as illustrated in Figure 7 for example.

7 [0085] As indicated above, the two louver doors 54,56 cooperate with the inner blocker door  
8 58 using the corresponding drive links 60 therebetween. Each of the two louver doors 54,56  
9 as disclosed above may be independently locked or latched using the corresponding toggle  
10 link 68 actuated by the common drive actuator 62 which rotates open or closed the louver and  
11 blocker doors.

12 [0086] An additional level or redundancy to lock or latch the louver doors stowed may be  
13 provided by introducing an interlock bracket or plate 92 fixedly joined to the radially outer  
14 surface of the inner blocker door 58 as illustrated in Figures 5, 6, and 14. Preferably, a pair of  
15 the interlock brackets 92 are mounted on the blocker door 58 spaced laterally apart from each  
16 other for matching the paired configuration of the other components of the louver and blocker  
17 doors.

18 [0087] As shown in Figure 5, the interlock bracket 92 is specifically configured for abutting  
19 contact with either or both outer louver doors 54,56 in the stowed positions thereof for  
20 interlocking the louver and blocker doors in their stowed positions. In this way, the common  
21 inner blocker door 58 itself may be used for additionally locking the doors in their stowed  
22 positions.

23 [0088] The interlock bracket 92 is best illustrated in Figure 7 and is preferably disposed at  
24 the aft end of the inner door 58 to correspondingly abut the aft ends of both outer louver doors  
25 54,56 when stowed.

26 [0089] Each interlock bracket 92 is in the form a thin vertical plate having axially forward  
27 and aft flanges in which corresponding adjustable stop pins 94 are suitably mounted. For  
28 example, the stop pins 94 may be in the form of threaded bolts mounted in threaded apertures  
29 in the flanges for adjusting their corresponding heights.

30 [0090] As shown in Figure 7, the forward stop pin 94 has a head oriented to abut the outer

1 side or surface of the forward louver door 54 near its trailing edge when stowed.  
2 Correspondingly, the aft stop pin 94 has a head oriented to abut the inner side or surface of the  
3 aft louver door 56 near its trailing edge when stowed.

4 **[0091]** Both aft ends of the two louver doors 54,56 are curved radially inwardly and spaced  
5 apart on opposite sides of the interlock bracket 92. The bracket 92 may therefore be suitably  
6 configured for mounting the forward and aft stop pins 94 closely adjacent to the corresponding  
7 portions of the two louver doors for abutting contact therewith when the two louver doors are  
8 stowed.

9 **[0092]** In Figures 5 and 7, the common inner blocker door 58 is closed in its stowed  
10 position, with in turn positions the interlock bracket 92 between the aft ends of the two louver  
11 doors so that the two stop pins 94 contact the two louver doors. This contact prevents the aft  
12 louver door 56 from being deployed, and prevents the inner blocker door 58 from being  
13 deployed, and in turn interlocks all three doors 54,56,58 together by the interlock bracket 92  
14 itself, which is in addition to the interlocking of the same three doors provided by the unison  
15 links 64 and drive links 60.

16 **[0093]** When the drive actuator 62 is retracted as illustrated in Figure 6, the louver doors and  
17 blocker door are simultaneously deployed which disengages the interlock bracket 92 from the  
18 two louver doors to permit deployment of all three doors.

19 **[0094]** Like the forward and aft toggle links 68 described above, the interlock bracket 92  
20 may be used with either louver door 54,56 or both louver doors. The interlock bracket 92 may  
21 include the forward stop pin 94 as illustrated in Figure 7 for abutting the forward louver door  
22 54 in the stowed position, or may include the aft pin 94 abutting the aft louver door 56 in the  
23 stowed position, or may include both forward and aft stop pins 94 for additionally interlocking  
24 all three doors 54-58 together.

25 **[0095]** The interlock bracket 92, like the toggle links 68, disclosed above provides additional  
26 locking or latching of the interconnected louver and blocker doors independently of the drive  
27 actuator 62 and associated links 60,64. The drive actuator and its links not only control  
28 deployment and stowing of the several doors, but also provide the primary active mechanism  
29 for locking closed those doors to prevent inadvertent deployment thereof when not intended,  
30 except for landing of the aircraft.

1 [0096] However, in the event of any failure in the drive actuator 62 or links 60,64, or in the  
2 control system therefor, the toggle links 68 and interlock bracket may still be used to provide  
3 additional and redundant locking mechanisms for the several doors to prevent their  
4 inadvertent deployment. The forward toggle link 68 provides one level of redundancy for  
5 locking closed the forward louver door, which in turn locks closed the aft louver door and  
6 blocker door by the interconnected links 60,64.

7 [0097] The aft toggle link provides another level of locking redundancy for the aft louver  
8 door 56, and in turn the forward louver door and blocker door interconnected by the links  
9 60,64.

10 [0098] And, the interlock bracket 92 provides yet further levels of locking redundancy with  
11 the aft stop pin locking closed the aft louver door, and the forward stop pin locking closed the  
12 cooperating blocker door, with all three doors being interlocked closed together.

13 [0099] These multiple levels of locking redundancy are all passive and simply effected upon  
14 initial stowing closed of the several louver and blocker doors as initially driven by the drive  
15 actuator 62. That drive actuator generates sufficient force for not only deploying open the  
16 several doors but also overcoming the reaction force in the toggle links as they are compressed  
17 to toggle past their corresponding toggle lines during deployment. The interlock bracket 92  
18 itself is simply freed from abutting contact between the forward and aft louver doors as the  
19 three doors are simultaneously driven open.

20 [0100] Figures 5 and 15 illustrate an exemplary embodiment of additional means for  
21 actively locking closed the outer and inner doors 54-58 in their stowed position, with Figures  
22 6 and 16 illustrating unlocking of the doors during deployment. As best shown in Figure 15,  
23 the locking means include a locking bracket or tab 96 fixedly mounted inside the forward end  
24 of the forward louver door 54. A locking actuator 98 is fixedly mounted inside the nacelle and  
25 has an extendable rod aligned with the locking tab for engaging an aperture therein to lock  
26 closed the forward louver door 54 when stowed. Retraction of the actuator rod releases the  
27 locking tab 96 and permits deployment of the louver door.

28 [0101] The locking actuator 98 is independent of the drive actuator 62, and these actuators  
29 may have any conventional configurations such as electrical, hydraulic, or pneumatic with  
30 corresponding output rods that may be retracted or extended as desired.



1 [0102] As additionally shown in Figures 15 and 16, the locking means preferably also  
2 include a spring-loaded retainer 100 mounted to the nacelle adjacent the distal end of the  
3 output rod of the actuator. The retainer 100 provides many functions.

4 [0103] For example, the retainer 100 includes a corresponding bracket with an aperture  
5 therethrough in which the complementary tab 96 may nest as illustrated in Figure 15 so that  
6 the distal end of the actuator rod 98 may fixedly lock the tab in the retainer.

7 [0104] As shown in Figure 16, the distal end of the actuator rod includes an annular flange  
8 which may be captured by a corresponding tab that is spring-loaded in the retainer for  
9 retaining retracted the rod of the locking actuator when the doors are deployed open. In this  
10 way, the locking actuator may be de-energized while the retention tab prevents the actuator  
11 rod from extending into the retainer bracket. Preferably, the rod in the locking actuator 98 is  
12 spring-loaded to automatically extend when de-energized, so that upon retraction of the  
13 retention tab the rod can automatically extend.

14 [0105] The retainer 100 illustrated in Figure 16 also includes a radial pin around which a  
15 compression spring is mounted, with the tab 96 including a corresponding land for depressing  
16 inwardly the spring-loaded pin as the blocker door is stowed. In this way, the retracting pin in  
17 turn retracts the retention tab for unlocking the actuator rod. The actuator rod may then be  
18 driven to re-engage the apertures in the retainer 100 and tab 96 as illustrated in Figure 15 for  
19 locking the forward louver door.

20 [0106] For failsafe operation in the event of failure of the spring-loaded retainer 100, the tab  
21 96 includes an inclined cam surface below the aperture therein configured for engaging the  
22 distal end of the spring-loaded actuator rod for self-retraction as the louver door is stowed.

23 [0107] Whereas the drive actuator 62 and the lock actuator 98 are both active devices which  
24 must be externally powered for locking closed the louver and blocker doors, the relatively  
25 simple toggle links and interlock bracket permit locking or latching of the interconnected  
26 louver and blocker doors in a simple and passive manner. The toggle links and interlock  
27 bracket use the louver doors and blocker door themselves in interlocking together these doors  
28 without the need for external power. Multiple levels of locking redundancy are provided, and  
29 correspondingly decrease the complexity of the required locking redundancy over that  
30 typically required for conventional fan thrust reversers.

1   **[0108]**   While there have been described herein what are considered to be preferred and  
2   exemplary embodiments of the present invention, other modifications of the invention shall be  
3   apparent to those skilled in the art from the teachings herein, and it is, therefore, desired to be  
4   secured in the appended claims all such modifications as fall within the true spirit and scope of  
5   the invention.

6   **[0109]**   Accordingly, what is desired to be secured by Letters Patent of the United States is  
7   the invention as defined and differentiated in the following claims in which I claim:

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